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Biological Diversity, Land Degradation and Sustainable Rural Livelihoods

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Abstract: The 1998 Conference of Parties to the *Convention on Biological Diversity* asked national governments to demonstrate the importance of biological diversity in supporting rural communities. This paper introduces 'agrodiversity' as the primary way in which farmers use biological diversity and, more generally, the natural diversity of the environment for production, including their choice of crops, and management of land, water and biota as a whole. Promoting agrodiversity and understanding how it functions in tropical smallholder farming systems is the best way that importance may be shown.

A win – win scenario is presented which links agrodiversity to land degradation control and sustainable rural livelihoods as evidenced by food security. It is argued that policies that encourage biological diversity in areas of land use will not only meet countries' responsibilities under the Convention but will also address land degradation problems and support to rural livelihoods. The human significance of various types of biological diversity is shown. Sustainable rural livelihoods are presented in the new capital assets framework to demonstrate how rural households may use various components to control land degradation. To enable agrodiversity to be implemented practically, it has been codified into core elements of: biophysical diversity, the diversity of the natural environment that controls the resource base for food production; management diversity that embraces the practices (many of them indigenous) of farmers such as live hedges, soil amendments and ridge tillage techniques; agro – biodiversity which is the diversity of crop, plant and animal combinations; and organisational diversity, the way that farms are owned and operated, and the way that capital assets are allocated. Each element is then systematically related to show how agrodiversity controls land degradation and how it promotes food security. The example of the maize – Mucuna system in South America is cited as an evident demonstration of the value of agrodiversity to both soil conservation and to smallholder farmers' livelihoods.

Key words: Biological diversity, Agro – biodiversity, Agrodiversity, Land degradation, Livelihoods, Food security, Rural development, Sustainability

Introduction

The United Nations Convention on Biological Diversity, signed at the Earth Summit in Rio de Janeiro in 1992, and ratified by most developed countries (but not the United States) in 1994, set out a global agenda for the conservation and sustainable use of biodiversity and its components. It affirmed the sovereign rights of states over their biological resources and, crucially, it stated a principle that the benefits of development of biological resources should be shared fairly and equitably on mutually agreed terms. This paper is about these very benefits of biological diversity. It concentrates on the lives of disadvantaged people – those living in degraded, poor and marginal environments, for whom global benefits may seem an irrelevant luxury. It highlights the situations of those living in underdeveloped, often tropical, parts of the world, for whom development aid is usually targeted.

Biological diversity has traditionally been a central concern of ecologists. Yet for many non – ecologists, it remains conceptually elusive (Rodda, 1993). Treated with suspicion by some, 'biodiversity' means different things to different people. Some observers look upon it as a bandwagon for their pet agendas, while oth-

ers bemoan the loss of precision and rigour in debates on conservation priorities (Blaikie and Jeanrenaud, 1997). Referring to the variety, or the number, frequency and variability of living organisms and the ecosystems in which they occur, biodiversity itself encompasses diverse aspects. It includes: species diversity, which is the number and frequency of species of plants, animals and micro – organisms; intra – species and genetic diversity, the variety between plants of the same species and of genes within each species; and ecosystem diversity, the different types of animal – plant assemblages and their associated ecological processes. Assertions as to the threats to humans and global life – support mechanisms by loss in biodiversity (e. g. Wilson and Peters, 1988), and supporting arguments on the benefits and potential values of biodiversity (e. g. McNeely, 1988) always came from ecologists. It was only in the early 1990s, with the rise of ecological economics and political ecology (e. g. Swanson, 1995, an edited compilation of contributions equally from socio – economists and natural scientists), that biodiversity entered a very different arena – one that would attract pragmatic, immediate and purposeful reasons why protection of biodiversity is essential. So it was that the 1998 Third Conference of Parties to the Convention on Biological Diversity, meeting in Bratislava (COP3/CBD), asked countries to document and demonstrate the importance of biological diversity in addressing problems of resource depletion and supporting rural communities. This paper arises from this fundamental shift in thinking: from biodiversity being an ethical but esoteric concern of natural science to biodiversity being a foundation for human livelihoods and sustainable development.

Taking up the challenge of COP3, the objective of this paper is to provide an early but evident demonstration of the central importance of biological diversity to addressing the old problem of the depletion of environmental resources and the more newly articulated problem of poor people's survival. It brings together three terms – agrodiversity, land degradation and rural livelihoods – that are all receiving substantial, but usually separate, attention in current debates about global futures and how human society can sustain development.

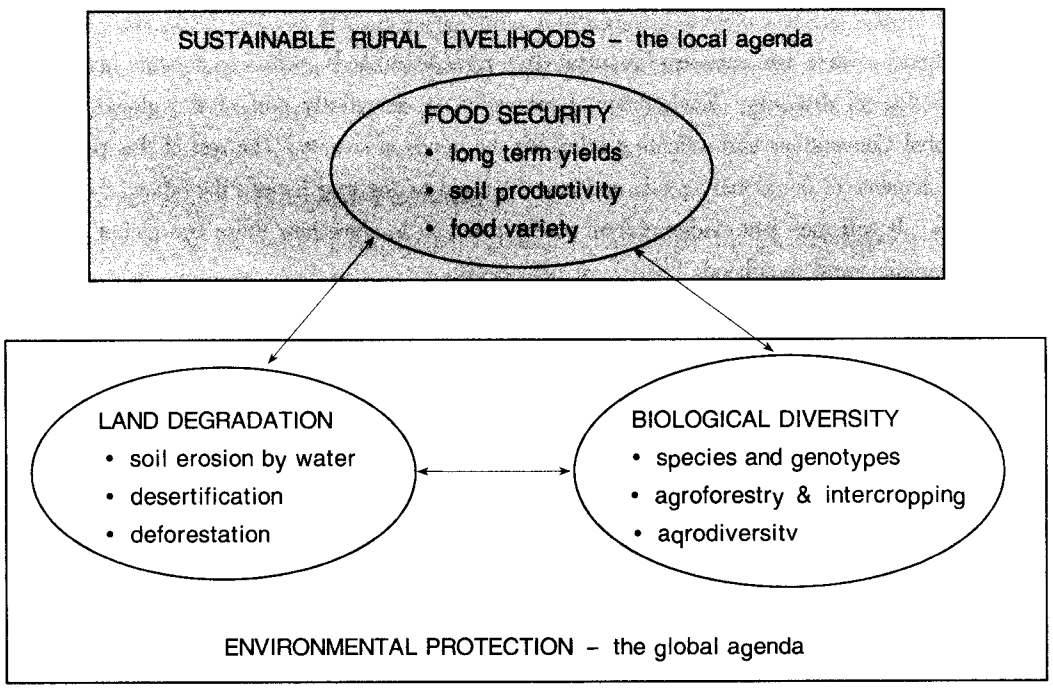


Figure 1. A win – win scenario. Situating agrodiversity and land degradation in the sustainable rural livelihood debate and global environmental agendas. (adapted from Tengberg and Stocking, 2000)

A Framework for Sustainable Rural Livelihoods and Environmental Protection

In parallel to the change in thinking about the importance of biodiversity, approaches to human welfare in relation to the biophysical environment have also undergone radical shifts (World Bank, 1992). No longer is development simply the transfer of technology or delivery of economic support from an altruistic donor to a grateful recipient. It is far more complicated. Yet there are still searches for some 'magic' formula that will ensure that the agendas of both the recipients of aid (e. g. economic development and poverty – relief) and the givers (e. g. biodiversity conservation) are met. One such is the appealing notion that the biophysical environment can be looked after while simultaneously providing for the immediate and felt needs of human populations – the World Bank's win – win scenario. It has driven international development policy on some of the seemingly most intractable human problems, such as population growth and environmental decline in Africa (Cleaver and Schreiber, 1994). In part, the notion is a reaction to the widespread environmental pessimism of the 1960s and 1970s. Partly also, it has been fuelled by burgeoning evidence that environmental recovery has, in places, happened spontaneously (Tiffen et al, 1994) and that policies and practices have, maybe inadvertently, had positive effects on old problems such as deforestation (Fairhead and Leach, 1996) or soil erosion (Critchley, 1999). Some traditional soil conservation methods such as trashlines in drier parts of Kenya, maintained against professional advice which would rather have terraces dug, have only lately been shown to be both economic and technically – efficient (Kiome and Stocking, 1995). If such positive things have happened without (or even despite) planning, imagine – the argument goes – what could happen if the ingredients for a win – win could be identified. Then, their effects could be analysed and the techniques could be appropriately supported. There is now much attention in the literature to the search for alternatives, asking questions such as: "Can agricultural growth be compatible with natural resource conservation and at the same time create the conditions for improving livelihoods and reducing poverty?" (Ellis – Jones, 1999). Much of this attention has been devoted to indigenous technologies, especially in the more difficult, arid parts of the tropics (Kerr and Sanghi, 1992).

Figure 1 presents a win – win scenario for sustainable rural livelihoods, with components involved in land degradation and biological diversity. Environmental protection is essentially part of the global agenda, enshrined in two global Conventions and reflecting primarily the needs of society. The rest of this paper will look first at these two elements of the global agenda and how attention to one may benefit the other (the lower shaded box of Fig. 1). It will then use evidence from recent research to show how these two global agenda items may address sustainable rural livelihoods (SRL) for poor people.

Land degradation – part of the global agenda

Under the UN Convention to Combat Desertification (CCD), desertification is defined as land degradation in arid, semi – arid and dry sub – humid areas.[①] Article 1 of the CCD describes ' land' as the terrestrial bio – productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system (World Bank, 1996). ' Land degradation' therefore means the reduction or loss of biological and economic productivity of major land uses (rainfed cropland, irrigated cropland, rangeland, forest) resulting from processes arising from human activity, such as soil erosion, change in physical, chemical or biological soil properties, and long – term loss of natural vegetation. In giving priority to Africa, the CCD recognises that the most intractable degradation problems are in the dryland agricultural and livestock

① Notwithstanding the title of the Convention, the term 'desertification' is increasingly being avoided. Pagiola (1999) cites two reasons: the vagueness and imprecision of its definition, and the controversy over whether a process which has its major emotional impact in images of advancing sand dunes should be described as a real phenomenon. The GEF Operational Programs also studiously avoid the word.

practices of subsistence land users.

Land degradation causes problems at three levels (Pagiola, 1999). At the field level, it results in reduced productivity. This will be discussed later in the context of food security and the local SRL agenda. At the national level, land degradation has large off – site effects, including flooding, sedimentation, effects on water quality and reductions in water supply. In developed countries such as the USA, these off – site impacts are calculated as many times larger than on – site changes in soil productivity (Crosson and Stout, 1983). In less developed areas such as Java, the opposite seems to pertain (Magrath and Arens, 1989). Caution does, however, need to be exercised in these national estimates because economic valuation approach and the perspective adopted substantially affect such calculations (Enters, 1998).

At the third level (global), land degradation has a number of complex direct and indirect interaction effects, including:

- *climate change through emissions of greenhouse gases* – agriculture contributes a third of total carbon dioxide emissions, the vast majority of which derive from tropical deforestation.
- *Reduction in terrestrial carbon sinks* – the world's topsoils store about 60% of total stock of carbon that enters the biological cycle. Land degradation is the principal threat to the size of the soil carbon stock.
- *Diminished effectiveness of carbon cycling* – reduced production of vegetation results in lower subsequent carbon inputs, which in turn promotes further land degradation.
- *Reduction in biodiversity* – below ground, soil organisms are vastly reduced on degraded soils, while above ground, degraded landscapes are unable to support the total amounts and varieties of biological species that occupy fertile areas.
- *Pollution and sedimentation of international waters* – an off – site effect with global, or at least international, implications that has attracted projects under the global funding mechanism, the GEF.

Many of these global aspects of land degradation have major implications for its control through the use of biological means. This link will be explored in the following two sections: the first in another global agenda item, and the second through food security presented as part of the local agenda of SRL.

Biological diversity – the global agenda

Biodiversity is characterised by variety and variability. Although usually associated with wild nature and protected areas, the *Convention on Biological Diversity* has encouraged a much broader and pragmatic interpretation of the term to mean the variety of all life on earth, whether wild or domesticated (Koziell, 2000). This variety is both spatial and temporal. Living things interact within and between themselves, and also with the inorganic environment of atmosphere, soil and water. These interactions give rise to constantly changing networks of relationships, as living things adapt in response to natural or human – induced pressures. Human society taps into these interactive relationships, primarily through its utilisation and modification of food chains, and the attendant processes such as photosynthesis. Biodiversity is a fundamental life – support mechanism, sustaining the interconnectedness of life and adaptation to changing conditions. Table 1 presents a partial view of how different components of biodiversity are significant to life – support, showing how the human significance may impact at all levels from the local to the global.

The presentation in Table 1 of the importance of biodiversity to human society is a somewhat standard view. Many observers, even those working directly on biodiversity issues, are sometimes dismissive of the conservation of biodiversity as "important only up to a point for the sustainability of agricultural production." (p. 9, Tisdell, 1999). Different authors variously advance five main reasons for why biodiversity is so important to

human society:

Table 1 Types of biodiversity and their human significance (adapted from Koziell, 2000)

Type of diversity	Human significance	Individual Components
Ecosystem diversity – biodiversity at landscape level, with distinct groupings of living things	Interactive processes within and between species, providing ecological resilience; interactions with physical environments, enabling hydrological and nutrient cycling, and major accumulations of energy.	Species combinations at multiple levels; from ecosystems occupying different parts of landscapes, to species within a single ecosystem.
Species diversity – biodiversity in its classical sense, being the distribution and abundance of species within a community or an area. Includes species richness.	Provision of a range of biological resources, required for survival. Includes food, fodder, and fuel. Reduction in risk, if one species should fail.	Variety in species of birds, mammals, invertebrates, plants, fungi, micro – organisms. Sub – species and varieties, including cultivars, landraces and domesticates.
Genetic diversity – biodiversity in frequency and variety of genes and/or genomes within populations and species. Includes differences between genes on the same chromosome.	Creates hereditary variation within species, offering opportunity to choose genetic characteristics which relate to yield, taste, palatability, nutrition, drought resistance, etc.	Alleles, phenotypes, DNA sequences

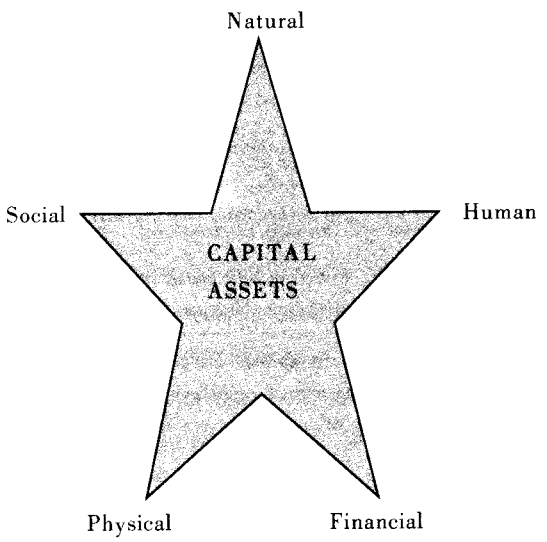
- **greater functionality**: diversity within and between species gives them differing characteristics, enabling more roles and functions to be undertaken;
- **intergenerational equity**: future human societies may become dependent on living resources preserved now, without apparent current productive benefit;
- **better resilience and stability**: agro – ecological systems are more resilient and sustainable if they possess greater genetic diversity, though empirical evidence is far from conclusive (Perrings et al, 1995);
- **flexible response to changing needs**: biodiversity enables living organisms to adapt to changing conditions and external pressures;
- **ecosystem and life – support service role**: energy conversion and material exchanges, which are necessary for maintaining a productive, healthy and stable environment, are supported by biodiversity.

Biodiversity, then, is the source of many goods and services for society at a variety of functional levels. Of particular practical interest at the global and international levels are:

- **Conservation** of genetic material of future importance to society: medicines and chemicals not yet discovered – i. e. future use value.
- **Preservation** of genetic material currently useful to society but not yet widely disseminated. Germplasm trading and exchange could become vital to developing countries.
- **Risk reduction** in material provision during times of environmental stress and scarcity.
- **Production** benefits through selection of more productive species and varieties. Continued access to genetic resources is crucial.
- **Diversification** by increasing global production of a greater range of crops.

Returning to the win – win scenario in Figure 1, biological diversity is well equipped to provide benefits both to society at large and to local people. Most of the benefits considered above can equally be considered as positive aspects for rural people. Furthermore, they are aspects, which are maintained by these beneficiaries, when they manage their biophysical resources of plants, soil, water, climate and land. This is what this paper will be calling agrodiversity. But before considering these complex linkages, the final component of the win –

win framework is sustainable rural livelihoods (SRL), which is covered in the following section.



Natural capital: natural resource stocks, from which flow resources to support livelihoods.

Social capital: social resources, from which flow information, mutual help, emotional support and physical asistance.

Human capital: all directly productive aspects deriving from humans, such as intellectual skills, knowledge, physical strength. Labour and gender are ttwo that feature most in determining investments in the land.

Physical capital: the basic infrastructure and the production equipment and means, such as tools, transport, ebnergy and access to water.

Figure 2. Capital assets components of Sustainable Rural Livelihoods. (after Carney, 1998)

Sustainable rural livelihoods (SRL) – the local agenda

In the last five years a new focus for development aid assistance has arisen – the SRL approach. It is being embraced by development agencies, such as the UK's Department for International Development (Carney, 1998). The approach is distinct from previous donor efforts such as 'Integrated Rural Development Planning' (IRDP) of the 1970s and sectoral project planning of the 1980s. Above all, it is people – centred, rather than focussing on geographical areas or needs and resources. It targets poverty, complexity, local knowledge and skills, while attempting to relate policy with practice through partnerships and participation. It takes the opportunity to mainstream environmental concerns (such as land degradation or loss in biodiversity) as part of livelihood development, rather than just adding it as another donor – led requirement. A good illustration of the different emphasis is the typical location of SRL projects in contrast to its predecessors. IRDPs were stand – alone projects with separate management and defined geographical areas. Sectoral projects were usually located in a host organisation, often a government department or ministry, building competence in service functions such as soil survey or planning. SRL projects are within a partner organisation (not a 'host') such as an NGO, development authority, local government or private sector company.

A framework for SRL has recently been developed in order to concentrate the focus on people, their needs and their opportunities (Scoones, 1998). Intended to be a simple but practical tool, the framework concentrates on five different assets upon which individuals may draw in order to build their livelihoods (Figure 2). Table 2 develops examples of how the availability or unavailability of these capital assets may affect land degradation positively or negatively. Thus, for example, one important asset component affecting land degradation is 'social group'. Disruptions to society through conflicts and wars are well known to cause environmental stress through refugee movements and people's unwillingness to invest in land improvements when the future is so uncertain (Black and Sessay, 1997). Alternatively, long – settled and cohesive communities and social groups tend to develop their own tried and tested technologies, including a wealth of conservation measures such as ridges, planting pits and mulching methods (Tengberg *et al*, 1998)

Table 2 Examples of capital assets components related to land degradation.

Capital Assets Group	Component	Positive Relation to Land Degradation	Negative Relation to Land Degradation
Natural	Land	**Sufficient lands to plant grass strips or shelter belts.**	Insufficient land to devote to non – consumptive uses such as conservation.
	Soil	Resilient soil able to withstand continuous cultivation without yield loss (e. g. nitosol)	Sensitive soil that loses fertility easily, which has large impact on yields (e. g. luvisol)
Social	Social groups	Indigenous and adapted techniques of soil and water conservation developed.	Social disruption, conflict, wars
	Access to institutions	Effective agricultural extension and subsidy regimes.	Ineffective agricultural extension and lack of access to technologies.
Human	Labour	Sufficient labour to intensify and invest in soil improvement.	Extensification and poor agricultural practice because of insufficient labour.
	Gender	Womens' management of home gardens using composting, ridges and inter – cropping	Overburdened women unable to undertake soil improvement
Physical	Implements	Availability of ridging implements to construct earth bunds.	Conventional tillage only, encouraging excessive erosion.
	Transport to market	Market opportunities provide further investment in land.	No cash income – subsistence cultivation only and soil mining.
Financial	Cash income	Sufficient cash to invest in land and soil improvement.	Non – farm cash income sources discourage investment in soil.
	Credit	Land users enabled to plant on time and minimise erosion.	Intermittent crop failure, debt and necessity to seek off – farm income.

Only in the 1990s has a new style of natural resource intervention emerged that is based on holistic and participatory planning at community and village level. To illustrate one such example and how the components of the SRL approach may provide better insights into practical solutions to land degradation, consider the gestions de terroirs of West Africa. Loosely translated as 'management of village lands', projects using the gestions de terroir approach start with the participatory identification of resource problems. Guèye (1995) describes the types of tools such as resource maps, Venn diagrams and wealth classification, as well as the use of local knowledge. This leads to the development of village institutions to address resource management decisions and implementation, monitoring and evaluation of activities (Toulmin, 1993). The approach emphasises a number of important aspects of sustainable rural livelihoods:

- local diagnosis of problems – using those who live with the problem to articulate a need to address the problem
- establishment of boundaries of responsibility – those who do the work, reap the benefit
- development of a village management plan and map – to encourage a continuing involvement and recognition that needs in one place differ from those in another
- regular monitoring and evaluation – an iterative cycle of learning and adjustment of activities.

While certainly not a panacea, Reij *et al* (1996) consider gestions de terroirs a more promising way forward than standard solutions. Village – based land management highlights the need to combine all material, social and physical resources towards achieving sustainable support to livelihoods. Because of local empowerment and central involvement by land users, gestions de terroirs also stand a far better chance of accurate diagnosis of land degradation problems and committed land management. They are also more likely to rely on the intrinsic biological resources available at village level, rather than external interventions and imported inputs. The next section will develop the concept of 'agrodiversity' to show these biological resources both control

land degradation and support livelihoods.

Agrodiversity

Biological diversity has a crucial ecological role in agro – ecosystems (Altieri, 1999). In addition to food production, it performs ecological services in nutrient cycling, regulation of microclimate, suppression of undesirable organisms and detoxification of noxious chemicals. Most authors call this 'agricultural biodiversity' or 'agro – biodiversity' (e. g. Thrupp, 1998). Brookfield and Padoch (1994), however, coined the term 'agrodiversity' to describe various biodiversity – related attributes of tropical small farm systems. They gave examples of farming systems that are resilient to external pressures and able to provide assured and sustainable production through the local management of biological diversity. Since then, the concept of agrodiversity has expanded to include the variety of practices developed by farmers that ensure them of production and enable them to withstand the vagaries of often difficult environments. Agrodiversity refers to interactions between agricultural management practices, farmers' capital assets and the diversity of species (e.g. Netting and Stone, 1996).

There are four main reasons why agrodiversity should be a useful focus of interest today. First, there is more plant biological diversity in areas of land use in the tropics and sub – tropics than in all protected areas. As human populations increase, protected areas will become an increasing luxury and hence even their role in maintaining the stock of biodiversity will be under threat. So, it makes sense to concentrate our efforts on keeping biodiversity in agricultural systems. Secondly, small – farm agricultural systems are the primary custodians of this biological diversity. A survey for the PLEC project (see Acknowledgements) in one site in SW China by Guo Huijun and co – workers revealed over 110 types of managed agroforestry and 220 different associations of trees, crops and livestock. In such situations, local adaptation has effectively maintained biodiversity and even enhanced it. Thirdly, much of this knowledge and management of biodiversity is slipping away under the pressures to commercialise, mechanise and standardise. In particular, only the elderly now holds knowledge of local plants such as medicinal species; chemicals have superseded many locally developed pest management practices; and many soil fertility maintenance techniques are now reliant on inorganic inputs. Finally, however, there is an increasing recognition that agrodiversity might hold lessons for agricultural development, especially in accessing techniques that would improve the situation of the rural poor.

Agrodiversity is largely a response of resource – poor farmers to inherent spatial and temporal environmental variability (e.g. the case of semi – arid farmers in Kenya; Tengberg *et al*, 1998). Brookfield and Stocking (1999) have codified agrodiversity into four principal elements, all of which have major implications for livelihoods and control of land degradation:

(1) *Biophysical diversity*. This is the diversity of the natural environment, which controls the intrinsic quality of the natural resource base for food production. Soil productivity, the biodiversity of natural plant life and of the soil biota are included. It crucially involves knowledge of earth surface processes and interactions between organic and inorganic components, such as the control of land degradation by water erosion through vegetation cover. Farmers select within this biophysical diversity and may manipulate it substantially for both livelihoods and land degradation control purposes.

(2) *Management Diversity*. This involves all methods of managing land, water and biota for crop production and the maintenance of soil fertility and structure. Smallholder farmers have a wide range of practices using biological, chemical and physical means such as live hedges, calcium – rich soil amendments and tillage techniques. Such practices not only enable more assured production and livelihood benefits but also act as soil and water conservation techniques.

(3) *Agro – biodiversity*. This is the management and direct use of biological species, including all crops, semi – domesticates and wild species. In agricultural systems, the diversity of crop combinations, and the manner in which these are used to sustain or increase production, reduce risk, and enhance conservation, are aspects of agro – biodiversity important to livelihoods and environmental protection.

(4) *Organisational Diversity*. This is the way in which farms are owned and operated, and the way that capital assets are allocated. Farmers with different resource endowments organise differently in accord with their specific circumstances. Explanatory elements include labour, household size, off – farm employment, gender roles and dependence on farm income. Flexible responses to external factors and market opportunities are made possible, thus enabling better support to livelihoods.

Brookfield and Stocking (1999) argue that these categories are fundamental to understanding the interface between natural biological diversity and human land use. This management of variation within agro – ecosystems (Almekinders et al, 1995) is now acknowledged as the principal way forward to achieve the win – win scenarios such as that described in Figure 1. Two benefits of agrodiversity will now be considered – control of land degradation and promotion of food security:

How agrodiversity controls land degradation

Through the greater use of biological processes and of techniques adapted by farmers to the local environment, agrodiversity reduces both the risk of land degradation and its potential impact on production and livelihoods. This is achieved in complex direct and indirect ways through combinations of:

- better and more continuous vegetation cover intercepting rainfall erosivity
- promotion of water infiltration along root channels and in soil with better structural stability
- control of runoff and sedimentation by stems and surface organic matter
- increased organic matter and enhancement of soil productivity encouraging greater vegetation growth and better protection to the soil
- increased soil organic matter reducing soil erodibility
- reduction in need for costly conservation structures and other inputs
- better production and financial returns enabling further capital investment in land improvement.

These ways may be exemplified through the four principal elements of agrodiversity.

Biophysical diversity includes the natural resilience of the biophysical environment, which is buffered by increases in organic matter. This increased organic matter reduces land degradation. For example, Elwell (1986) has shown conclusively on high – clay Zimbabwe soils that the stability of water – stable aggregates is crucially dependent on maintaining an organic carbon level of 2 percent or more. Below this threshold, aggregates break down quickly, surface sealing occurs, runoff accelerates and soil erosion results. Above this level, surface aggregates keep a good surface – water storage capacity, allow adequate infiltration and ensure optimal plant growth. Keeping this natural soil resilience relies on production of sufficient biomass, having a range of different types and qualities of organic materials and their reincorporation into the soil. Only an agrodiverse strategy of agricultural production can assure these attributes in a practical and realistic way for smallholder farmers.

Management diversity is often founded on local knowledge. Indigenous and adapted techniques of soil and water conservation are the most immediate way in which this form of agrodiversity may control land degradation. For example, Bunch and López (1999) have described how local innovation based on the use of mainly biological techniques has transformed many Central American rural areas. In one small community (Pacayas) in Honduras, 16 innovations have been added to the already biodiverse farming system: four new crops; two green manures; two new species of grass for use as contour barriers in vegetable fields; new chicken pens

made of king – grass; marigolds to control nematodes; the beans Dolichos lablab and Mucina pruriens to feed cattle and chickens; Napier grass to control landslips; and so on. An increasing number of studies now attempt to assess the knowledge that farmers hold and their experimentation practices in, for example, soil fertility improvement in Ethiopia by fallowing, manuring and use of crop residues (Corbeels *et al*, 2000). Management diversity in our agrodiversity framework expresses this wide variety of practices and innovations that use the attributes of many plant species. They add resilience to the whole farming system, and they increase production through conserving soil and water, improving soil fertility and controlling land degradation.

Agro – biodiversity is the single most direct way in which biological diversity can assist the control of land degradation. Having more plants over longer time periods substantially increases the vegetation cover to the soil. Having a greater variety of plants enables species to exploit the many micro – ecological niches within a farmer's field, again maximising vegetation cover. This cover has been demonstrated to be the single most influential factor in reducing erosion rates (Stocking, 1994). A monocrop of maize may typically have a mean annual vegetation cover of 30 percent. Under the same soil conditions, an intercrop of maize – velvetbean (see next sub – section) would have about 60 percent. This doubling of cover reduces erosion hazard to one – sixth of the maize monocrop situation. Agro – biodiversity includes the many complex sequential and spatial intercropping practices employed by farmers. It will include the many systems of agroforestry that are so well exemplified in smallholder farms. It also embraces multi – storey cropping in some of the world's most complex and productive agricultural systems, such as the Chagga home gardens in northern Tanzania and the Kandy multi – storey gardens in the hill lands of Sri Lanka. A good review of the many beneficial processes in agroforestry systems and how they directly affect the soil and control land degradation is by Huxley (1999).

Finally, organisational diversity expresses the variety between farms and plots of land, and of the use of different resource endowments and of different income and labour sources. Tengberg *et al* (1998) show how the characterisation of farmers into different resource levels largely explains broad differences in practice and land management. In this organisational diversity, the variables found most important in explaining farmers' engagement in local soil and water conservation practices were access to cash income, farm size, livestock ownership, labour availability, input use, cultivation methods and sex of head of household. Complex spatial patterns of uptake of the various techniques of conservation such as trashlines, Fanya – juu terraces, log – lines and stone bunds were found in Mbeere District of Kenya, depending on what this paper is calling 'organisational diversity'. Farmers' actual choice of conservation technique also related to type of soil and quality of land (biophysical diversity).

How agrodiversity promotes food security

One aspect of livelihoods presented in the framework for this paper (Fig. 1) is food security. Food security is primarily a function of maintaining assured production of food, and providing the variety of foods that society demands. This paper has already shown how agrodiversity has the potential to control land degradation. Implicit in this link is that control of land degradation, in turn, improves soil quality and increases production. Unfortunately, supporting data for these benefits of land degradation control are elusive. The more common database presents the reverse: that land degradation decreases crop yields. Nevertheless, it is a reasonable assumption that if land degradation had not occurred (i. e. conservation was practised), then yields would be saved (i. e. the yield that would have been lost without conservation). It is also reasonable, therefore, to assume that effective techniques of land degradation control enacted through agrodiverse strategies would also promote greater production and better food security.

Figure 3 presents the summary results from a large number of experiments sponsored by the UN Food and Agriculture Organization in Africa and South America. It shows the exponential nature of the general relation-

ship between erosion as a measure of land degradation and crop yield as a measure of soil productivity and food security. The steepness of the initial decline in yields is largely a function of the specific soil type, which is an aspect of biophysical diversity in this paper. However, actual decline in yields in a farmer's field is far more sensitively related to specific erosion rates. In terms of aspects that are amenable to farmer's management, erosion rates are primarily a function of vegetation cover. Putting these relationships together, Figure 4 presents the example of the FAO experiments for Cambisols. This soil is the typical tropical brown earth; very attractive to smallholder farmers as it has a reasonable intrinsic fertility, is easily cultivated and has few of the problematic aspects of many tropical soils, except that it can be rather stony. The suite of curves in Figure 4 give our best available evidence of the influence of management standard as assessed through vegetation cover (management diversity and agro – biodiversity). Clearly, the greater is the degree of agrodiversity, the more likely is it that yields on Cambisols can be maintained at reasonably productive levels with low inputs.

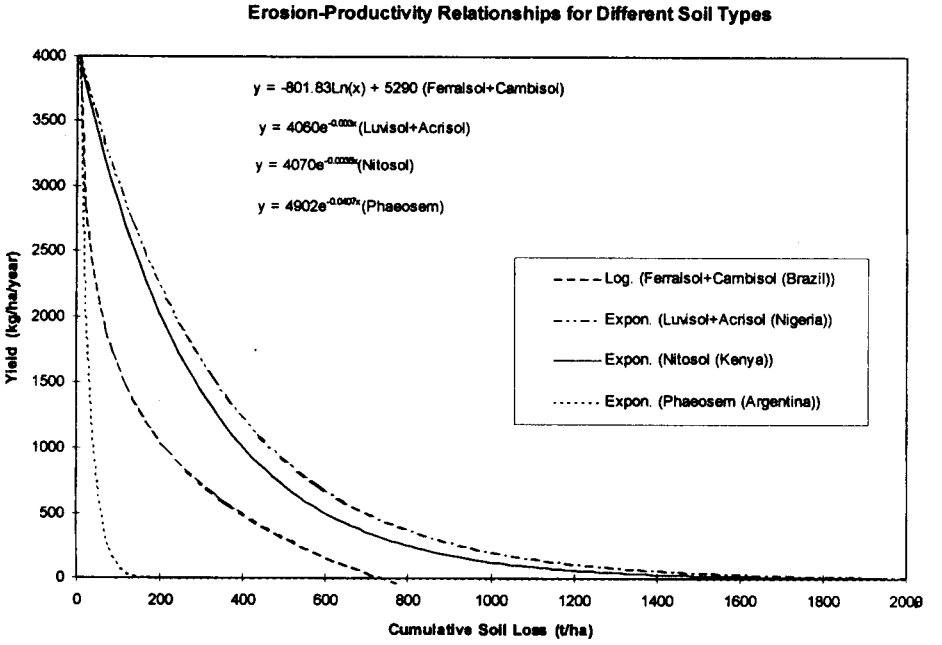


Figure 3 General erosion – productivity relationships for several major soil types, with initial maize grain yield on virgin land set to 4000 kg/ha. (Source: Tengberg and Stocking, 1997)

What sort of agrodiverse practices can provide for the better cover and for meeting real livelihood benefits in smallholder farming systems in the tropics? Only one, albeit quite remarkable, example will be presented here. The maize – Mucuna (velvetbean) system has been achieving enthusiastic acceptance in many South and Central American countries.

On the Ferralsols (Oxisols) in the western hilly parts of Santa Catarina State in southern Brazil, many smallholders used to gain only a precarious living through arable cultivation of maize on these very erodible soils. Conservation programmes had largely failed because the cost of structures was greater than any benefits to be gained in the short term. The maize – Mucuna system has transformed both the erosion situation and the maize – based livelihoods of local farmers. To account for this change, take the stages in a seasonal agricultural cycle. First, maize is directly drilled by hand (or with a horse – drawn drill) into the soil. Two weeks later, as the maize has started to germinate, Mucuna pruriens, a climbing legume bean seed, is also directly drilled. The maize grows rapidly and is harvested. The Mucuna is slower to grow, only reaching maximum growth rates after harvest of the maize. By the early dry season, the Mucuna completely covers all the maize

stalks with a dense mat of creeping biomass. Over winter the Mucuna dies back, forming a thick black mulch over the soil surface. In the second season, the farmer simply direct drills into this mulch for the new maize crop. The benefits are manifold:

- an increased yield of maize: the Mucuna is largely non – competitive with the maize, and farmers in southern Brazil relate how the benefits of the whole system translate to approximately tripled yields compared with monocrop maize;
- weeds are out – competed or completely stifled by the Mucuna mulch; this saves considerable labour at peak times;
- tillage is unnecessary, again saving labour and cost;
  in favourable sites, the Mucuna even sets sufficient seed to make replanting in future years
- unnecessary.

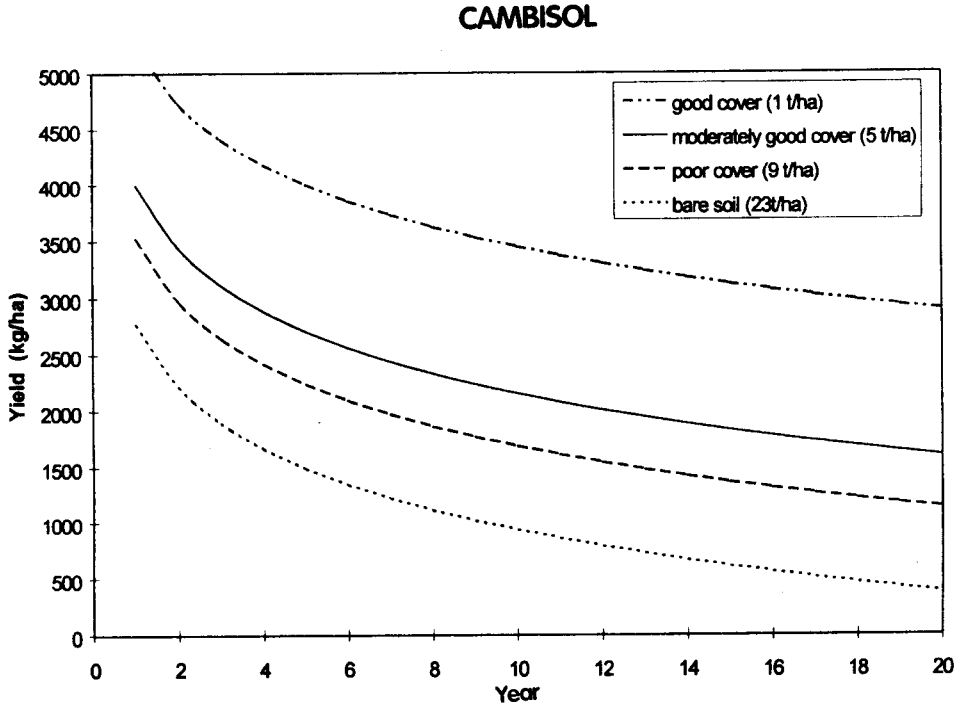


Figure 4 Maize yield scenarios with continued erosion for a Cambisol in a low input farming system with various degrees of vegetation cover. Typical annual erosion rates in tonnes per hectare for a 6% slope are shown for each cover level. (Source: Tengberg and Stocking, 1997)

The maize – Mucuna system is, therefore, an excellent example of how an intercrop (agro – biodiversity), managed in a way that avoids mechanical tillage (management diversity), using the substantial labour benefits of suppressing weeds (organisational diversity), while improving soil structure and chemical fertility (biophysical diversity), can transform rural livelihoods. It is a special case that was promoted by missionaries in many South American countries rather than by the extension system. Nevertheless, it is a classic demonstration of the value of agrodiversity.

Conclusion

'Biological diversity' is a term of our time. Its protection in areas of land use is now one of the highest priorities on the international agenda as expressed by the government signatories to the Convention on Biological Diversity. Yet, biological diversity remains an enigma. It is difficult for non – ecologists to link the term with

items of practical or economic relevance; modern agriculture is the antithesis of biodiversity; and rural development in the poorer parts of the tropics would seem to have far more pressing problems than protecting handfuls of obscure species and habitats. However, for the Convention to make headway, it is vital that biodiversity be seen in its pragmatic context, not only in ecologist's jargon as a "life – support system" but also in a real practical context making the environment more secure and people' s livelihoods better supported.

This paper has presented a framework whereby biodiversity may be viewed as a 'global agenda' linkage component with control of land degradation and the promotion of sustainable rural livelihoods. The framework is presented as a win – win scenario enabling both environmental protection and sustainable rural livelihoods to be tackled at the same time and by the same instrument – biological diversity in areas of land use, which this paper has presented in its broadest context as 'agrodiversity'.

Agrodiversity now needs to develop an empirical record as to its value, performance, sustainability and future potential. This is the objective of the PLEC project (see Acknowledgements below) which now has demonstration sites established in key areas of biological diversity, where agrodiversity is being shown to land users, scientists and professionals, and policy – makers as a desirable aim of policy and practice in agricultural development. Our sites are in Papua New Guinea, Southwestern China, Northern Thailand, Kenya, Uganda, Tanzania, Ghana, Guinea, Jamaica, Mexico, Amazonian Brazil and Peru.

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